Claims

What is claimed is:

[c1] A method of measuring whole body composition comprising:
confining movement of the body within a selected volume;
inducing a static magnetic field in the volume;
inducing a pulsed radio frequency magnetic field in the volume;
receiving nuclear magnetic resonance signals from the body, the static and radio frequency magnetic fields configured such that resonance signals from any part of the body are substantially independent of a position of the part within the volume; and
assessing whole body composition from the resonance signals.

[c2] The method of claim 1 wherein the pulsed radio frequency magnetic field includes substantially uniform spectral density within a predetermined frequency range, the frequency range related to a spatial distribution of the static magnetic field; and wherein the receiving is performed within a frequency range at least as large as the predetermined frequency range.

[c3] The method of claim 1 wherein the pulsed radio frequency magnetic field comprises composite radio frequency pulses to increase uniformity of nuclear magnetization within the volume.

[c4] The method of claim 1 wherein the pulsed radio frequency magnetic field comprises spectrally shaped radio frequency pulses to increase uniformity of nuclear magnetization within the volume.

[c5] The method of claim 1 wherein the receiving comprises receiving with a substantially uniform spatial sensitivity within the volume.

[c6] The method of claim 1 wherein the inducing the radio frequency magnetic field comprises generating at least one excitation pulse and generating a plurality of refocusing

pulses for each excitation pulse, and the receiving the resonance signal comprises measuring amplitudes of spin echoes.

[c7] The method of claim 6 wherein the excitation pulse and the plurality of refocusing pulses form a Carr-Purcell-Meiboom-Gill sequence, and each of the refocusing pulses reorients nuclear spin axes in the volume by about 180 degrees.

[c8] The method of claim 6 wherein the excitation pulse and the plurality of refocusing pulses form a Carr-Purcell-Meiboom-Gill sequence, and the refocusing pulses reorient nuclear spin axes in the volume by an angle within a range of about 90 to 180 degrees, the angle selected to reduce power consumption and to reduce radio frequency induced heating of the body.

[c9] The method of claim 6 wherein the excitation pulse and the plurality of refocusing pulses form a Carr-Purcell-Meiboom-Gill sequence, and the excitation pulse and the refocusing pulses each have a duration and nuclear magnetic spin rotation angles selected to make the frequency spectrum of the pulses broader than the frequency spectrum of nuclear magnetic spins that would obtain within a substantially homogeneous material disposed in the volume.

[c10] The method of claim 1 wherein the inducing the static magnetic field, the inducing the pulsed radio frequency magnetic field and the receiving are configured to acquire nuclear magnetic resonance signals corresponding to both transverse and longitudinal relaxation times of materials in the body.

[c11] The method of claim 1 wherein the static magnetic field has an amplitude selected to minimize a frequency of the radio frequency magnetic field for a selected size of the volume and a selected precision of measurement.

[c12] A method of measuring whole body composition comprising:
confining movement of the body within a selected volume;
inducing a static magnetic field in the volume;

inducing a pulsed radio frequency magnetic field in the volume, a spatial distribution of the static magnetic field and of the radio frequency magnetic field selected to minimize an objective function, the objective function including required measurement precision and at least one parameter related to cost of implementation of the method;

receiving nuclear magnetic resonance signals from the body; and

assessing whole body composition based on the resonance signals.

[c13] The method of claim 12 wherein the receiving the resonance signals comprises receiving with a substantially uniform spatial sensitivity within the volume.

[c14] The method of claim 12 wherein the pulsed radio frequency magnetic field includes substantially uniform spectral density within a predetermined frequency range, the frequency range related to spatial distribution of the static magnetic field; and wherein the receiving is performed within a frequency range at least as large as the predetermined frequency range.

[c15] The method of claim 12 wherein the pulsed radio frequency magnetic field comprises composite radio frequency pulses to increase uniformity of nuclear magnetization within the volume.

[c16] The method of claim 12 wherein the receiving comprises receiving with a substantially uniform spatial sensitivity within the volume.

[c17] The method of claim 12 wherein the inducing the radio frequency magnetic field comprises generating at least one excitation pulse and generating a plurality of refocusing pulses for each excitation pulse, and the receiving the resonance signal comprises measuring amplitudes of spin echoes.

[c18] The method of claim 17 wherein the excitation pulse and the plurality of refocusing pulses form a Carr-Purcell-Meiboom-Gill sequence, and each of the refocusing pulses reorients nuclear spin axes in the volume by about 180 degrees.

[c19] The method of claim 17 wherein the excitation pulse and the plurality of refocusing pulses form a Carr-Purcell-Meiboom-Gill sequence, and the refocusing pulses reorient nuclear spin axes in the volume by an angle within a range of about 90 to 180 degrees, the angle selected to reduce power consumption and to reduce radio frequency induced heating of the body.

[c20] The method of claim 17 wherein the excitation pulse and the plurality of refocusing pulses form a Carr-Purcell-Meiboom-Gill sequence, and the excitation pulse and the refocusing pulses each have a duration and nuclear magnetic spin rotation angles selected to make the frequency spectrum of the pulses broader than the frequency spectrum of nuclear magnetic spins that would obtain within a substantially homogeneous material disposed in the volume.

[c21] The method of claim 12 wherein the inducing the static magnetic field, the inducing the pulsed radio frequency magnetic field and the receiving are configured to acquire nuclear magnetic resonance signals corresponding to both transverse and longitudinal relaxation times of materials in the body.

[c22] The method of claim 12 wherein the static magnetic field has an amplitude selected to minimize a frequency of the radio frequency magnetic field for a selected size of the volume and a selected accuracy of measurement.

[c23] A nuclear magnetic resonance apparatus, comprising:

a magnet for inducing a static magnetic field within a selected volume, the magnet configured to provide a minimum static magnetic field amplitude with respect to a size of the volume and a selected accuracy of measurement, the magnet configured to induce a substantially homogeneous static magnetic field within the volume;

an antenna for inducing a radio frequency magnetic field within the volume;

means for generating radio frequency power pulses operatively coupled to the antenna;

means for detecting nuclear magnetic resonance signals from within the volume; and

means for analyzing composition of a body disposed within the volume from the nuclear magnetic resonance signals.

[c24] The apparatus as defined in claim 23 wherein the antenna is configured to have a substantially constant spatial sensitivity within the volume.

[c25] The apparatus as defined in claim 24 wherein the antenna comprises a longitudinally wound coil having a booster coil at each axial end thereof.

[c26] The apparatus as defined in claim 25 wherein an axial length of each booster coil is about one eighth an overall axial length of the antenna, and a coil turn density of each booster coil is about twice a turn density of a central portion of the antenna.

[c27] The apparatus as defined in claim 23 wherein the means for generating radio frequency power pulses is configured to produce a pulse sequence and the means for detecting is configured to measure spin echo amplitudes such that at least one of a transverse relaxation time distribution and longitudinal relaxation time distribution of a body disposed in the volume is determinable.

[c28] The apparatus as defined in claim 23 wherein the means for analyzing comprises means for determining fractional amounts of selected materials within a whole body disposed in the volume.

[c29] The apparatus as defined in claim 23 wherein the means for generating radio frequency power pulses comprises means for selecting a refocusing pulse angle to within a range of 90 to 180 degrees to reduce inductive heating of an object disposed within the volume.

[c30] The apparatus as defined in claim 23 wherein the means for generating radio frequency power pulses comprises means for generating substantially uniform spectral density in the power pulses within a selected frequency range.

[c31] The apparatus as defined in claim 23 wherein the means for generating radio frequency power pulses comprises means for generating composite pulses.

[c32] The apparatus as defined in claim 23 wherein the means for generating radio frequency power pulses comprises means for generating spectrally shaped pulses.

[c33] A nuclear magnetic resonance apparatus, comprising:
a magnet for inducing a static magnetic field within a selected volume;
an antenna for inducing a radio frequency magnetic field within the volume;
means for generating radio frequency power pulses operatively coupled to the antenna;
means for detecting nuclear magnetic resonance signals from within the volume, the magnet, the antenna and the means for generating configured to provide a maximum size of the selected volume with respect to physical dimensions of the magnet for a selected accuracy of measurement, the magnet, the antenna and the means for generating arranged to induce substantially uniform nuclear magnetization within the volume; and
means for analyzing composition of a body disposed within the volume.

[c34] The apparatus as defined in claim 33 wherein the antenna is configured to have a substantially constant spatial sensitivity within the volume.

[c35] The apparatus as defined in claim 34 wherein the antenna comprises a longitudinally wound coil having a booster coil at each axial end thereof.

[c36] The apparatus as defined in claim 35 wherein an axial length of each booster coil is about on eighth an overall axial length of the antenna, and a coil turn density of each booster coil is about twice a turn density of a central portion of the antenna.

[c37] The apparatus as defined in claim 33 wherein the means for generating radio frequency power pulses is configured to conduct a pulse sequence and the means for detecting is configured to measure spin echo amplitudes such that at least one of a transverse relaxation time distribution and longitudinal relaxation time distribution of a body disposed in the volume is determinable.

[c38] The apparatus as defined in claim 33 wherein the means for analyzing comprises means for determining fractional amounts of selected materials within a whole body disposed in the volume.

[c39] The apparatus as defined in claim 33 wherein the means for generating radio frequency power pulses comprises means for selecting a refocusing pulse angle to within a range of 90 to 180 degrees to reduce inductive heating of an object disposed within the volume.

[c40] The apparatus as defined in claim 33 wherein the means for generating radio frequency power pulses comprises means for generating substantially uniform spectral density in the power pulses within a selected frequency range.

[c41] The apparatus as defined in claim 33 wherein the means for generating radio frequency power pulses comprises means for generating composite pulses.

[c42] The apparatus as defined in claim 33 wherein the means for generating radio frequency power pulses comprises means for generating spectrally shaped pulses.

[c43] The apparatus as defined in claim 33 wherein an amplitude of the static magnetic field is selected to be substantially a minimum corresponding to a selected precision of measurement.